



DOSSIER · THERAPY

Strength Training

Strength training is broadly investigated as a training method in controlled studies, most densely at the musculoskeletal system. Noticeable is the dispersion: It is tested in osteoarthritis, heart disease, cancer, cirrhosis and sarcopenia. The most cited work in the field is a review on ageing, sarcopenia and falls, not an individual study.

1,349

STUDIES IN
TOTAL

949

IN HUMANS

701

OF WHICH
CONTROLLED

14

IN ANIMALS

3

IN THE LAB

Figures from the IHR study database · Last updated 2026-10-04

How to Read This Dossier

ESTABLISHED

measured in humans, with a comparison group

PLAUSIBLE

supported by mechanism, animal studies or observation

HYPOTHESIS

a likely connection that still needs to be tested

Resistance Training at a Glance

ORIGIN:

Resistance training, usually referred to in research as progressive resistance training, is a training method in which the muscle works against an external resistance — machines, weights, body weight or bands. It is defined by the increase in load over time: more weight, more repetitions, more sets or shorter rests. It is tested as high-intensity training or combined with balance and endurance components.

EVIDENCE BASE:

1,349 evaluated studies · 701 controlled human studies · 248 observational studies · 114 review articles · 14 animal studies · 2 cell-culture studies

STRONGEST EVIDENCE:

- Musculoskeletal system: The updated ACSM position of 2026, an overview of reviews, shows improved muscle strength, muscle size, performance and gait speed versus no exercise ²⁸.
- Osteoarthritis: In early knee osteoarthritis, resistance training improved mobility, walking distance and knee-extension strength versus control (SMD 0.46 to 0.81; GRADE moderate to high) ³⁰.
- Sarcopenia: Moderate intensity improved the 30-second chair-stand test (MD 2.98 repetitions), the timed-up-and-go test and hand-grip strength; according to the authors it is sufficient for many older adults ⁵².
- Cancer: Resistance training reduced the incidence of lymphoedema (odds ratio 0.25) and moderate-to-severe lymphoedema (odds ratio 0.21) and decreased upper-limb volume ³³.
- Mental health: Resistance training showed SMD -0.68, the most effective form tested against depressive symptoms, ahead of mind-body procedures and endurance training ²².

LIMITATIONS:

- Comparability: Training dose, intensity, progression, equipment and supervision vary widely; two studies with the same label can impose different stimuli.
- Blinding: A training stimulus cannot be blinded; double-blind, placebo-controlled designs therefore occur mainly with concomitant medication or dietary supplements, not with the training itself.
- Inconsistent: In type 2 diabetes a one-year programme did not improve mortality over 16.2 years; in colon cancer home-based training did not alter chemotherapy dose intensity.

CLASSIFICATION:

Resistance training is broadly studied and well established for the musculoskeletal system; for psychological and cardiometabolic endpoints the result depends strongly on the protocol and accompanying circumstances.

1. What Resistance Training Is

Resistance training, usually termed progressive resistance training in research, is a training method in which the muscle works against an external resistance. The resistance can come from machines, free weights, body weight or elastic bands. The method is defined by progressive overload over time — through more weight, more repetitions, more sets or shorter rests. In studies it is examined in highly varied forms: as high-intensity training or combined with balance and endurance components. Some studies investigate not the training alone but its combination with nutritional interventions, for example a protein-rich diet.

For the evaluation of all studies it is crucial that “resistance training” is an umbrella term and not a uniform intervention. Training dose, intensity, progression, equipment and supervision differ so markedly between studies that two studies with the same label can impose different stimuli. In addition, a training stimulus cannot be blinded: participants know whether they are training. Double-blind and placebo-controlled designs therefore occur mainly where concomitant medication or a dietary supplement is being tested, not the training itself. Target outcomes also vary — muscle strength, muscle size, walking ability, pain, quality of life or laboratory values such as interleukin-6 — and must not be interchanged.

2. What the Studies Show in Detail

The human studies, ordered by application and the controlled studies first — with participants, duration, preparation, outcome measure and result exactly as reported in the original papers. Numbers appear only where the study states them.

Distribution of **controlled human studies** by application area — the numbers are not additive because one study may be assigned to several areas:

APPLICATION AREA	CONTROLLED STUDIES
Musculoskeletal system	411
Safety and tolerability	187
Cognition and mental health	125
Fatigue and stress	115
Metabolism	114

APPLICATION AREA	CONTROLLED STUDIES
Oncology	82
Bones and joints	81
Heart and circulation	69

Resistance Training: Human Studies

The most robust foundation for the effect of resistance training on muscle function is provided by the updated American College of Sports Medicine position stand of 2026, an overview of reviews. Versus no exercise, resistance training improved muscle strength, muscle size (hypertrophy), performance, endurance, contraction velocity, gait speed, balance and several measures of physical function. Few prescription variables influenced the primary adaptations; voluntary strength increased more when heavier loads ($\geq 80\%$ of one-repetition maximum) were moved²⁸. For healthy adults the central statement is therefore broadly confirmed. What remains open is which combination of load, set number and frequency yields the greatest additional benefit beyond the variables examined here.

Endurance training, followed by resistance training, produced the highest effect on muscle strength (SMD 2.59; 95% CI 1.50 to 3.69); general remote training was most effective for fat-free mass (SMD 1.35; 95% CI 0.41 to 2.29) and physical performance (SMD 2.39; 95% CI 1.26 to 3.53). The combination of nutrition plus endurance and resistance training improved muscle strength (SMD 1.25; 95% CI 0.64 to 1.87) and performance (SMD 1.73; 95% CI 1.09 to 2.37). Resistance training alone improved several secondary endpoints: body-fat mass (SMD -0.57; 95% CI -0.75 to -0.40), blood inflammatory markers (SMD -1.69; 95% CI -1.95 to -1.43) and knee-extension strength (SMD 0.55; 95% CI 0.33 to 0.76)²⁹. The rankings rest on indirect comparisons; which intensity suits which baseline situation remains to be clarified.

Strength training with or without nutrition was consistently associated with better strength and performance values. Light to moderate intensity showed a positive effect only on handgrip (endurance training plus light to moderate intensity plus nutrition: MD 2.88; 95% CrI 0.43 to 5.32). Moderate intensity improved the 30-second chair stand test (MD 2.98 repetitions; 95% CrI 0.35 to 5.59), the Timed-up-and-go test (MD -1.74; 95% CrI -3.34 to -0.56) and handgrip (MD 2.44; 95% CrI 0.03 to 5.70)⁵². The authors conclude from this that moderate intensity is sufficient for many older people with sarcopenia. Whether higher intensities are safe and superior in frailty has not yet been examined.

In early osteoarthritis, strength training improved mobility, walking distance and knee extension strength versus control (SMD 0.46 to 0.81; GRADE moderate to high), as well as knee extension strength in later stages. Safety was analysed via risk differences³⁰. This provides a broad, stage-stratified evidence base for a common condition. Which prescription parameters are optimal in which stage remained open according to the research question.

Progressive strength training was more effective than control for lower-limb strength (SMD 0.57; 95% CI 0.17 to 0.96) and upper-limb strength (SMD 1.43; 95% CI 0.73 to 2.13). Aerobic fitness improved after progressive strength training (16.9%) similarly to endurance training (21.0%; SMD -0.13; 95% CI -0.35 to 0.08). Combined training was superior to endurance training alone for aerobic fitness (SMD 0.21; 95% CI 0.09 to 0.34) as well as for lower-limb strength (SMD 0.62; 95% CI 0.32 to 0.92) and upper-limb strength (SMD 0.51; 95% CI 0.27 to 0.74). Twenty studies reported adverse events¹. The safety statement rests on these reported events; uniform recording is lacking.

Strength training increased muscle strength (isometric handgrip: MD 2.50 kg; 95% CI 1.33 to 3.67; one-repetition maximum leg press: MD 19.28 kg; 95% CI 14.70 to 23.86) and muscle power (MD 29.52 W; 95% CI 28.84 to ...) ⁸. The authors emphasise that this was the first meta-analytic summary for this group. How the training integrates practically into ward routines in the acute hospital has not yet been clarified.

In compensated liver cirrhosis, a randomised controlled study from 2020 examined 39 patients (Child-Pugh A or B, outpatient clinic in Denmark) with 36 supervised units of progressive strength training of one hour each, three times weekly over 12 weeks, versus a control group without change in everyday activity. The training group increased its muscle strength by 13% (from mean 119 Nm to 134 Nm), an 11 Nm greater gain than in the control; muscle size was recorded as quadriceps cross-sectional area by magnetic resonance imaging⁴². The participant number is small, yet the results are concrete and directional. Whether the gain translates into everyday function and prognosis remains open.

In incomplete spinal cord injury, a single-blind randomised study from 2023 examined 28 participants over 12 weeks for the combination of progressive strength training and functional electrically evoked leg cycling versus electrically evoked cycling alone. Twenty-three participants completed the study (10 in the combination group, 13 in the comparison group; 18 men, 5 women; mean age 33.4 ± 9.7 years). The gain in isometric peak torque of the left hamstrings was consistently higher in the combination group with a mean difference of 4.5 ± 7.9 Nm (45% change, $p < 0.05$) than in the comparison group (2.4 ± 10.3 Nm; 4% change)²⁷. The sample size is small; the direction of the difference is consistent. Larger studies with functional endpoints are pending.

In advanced castration-resistant prostate cancer, a pilot study from 2021 examined 25 men over 12 weeks for the feasibility, safety and acceptability of remotely supervised training (1:1 endurance or strength training three times weekly or usual care). Twenty-three men (82%) completed the 12 weeks. Participants in the remote intervention attempted 90% of the prescribed endurance and 96% of the prescribed strength training sessions; 86% and 88% of the attempted sessions were completed as prescribed or more intensively. Performance tests showed changes consistent with the training²⁶. The study was designed for feasibility, not efficacy. Whether the training improves clinical endpoints must be shown by a larger study.

In colon cancer, the randomised controlled FORCE study from 2024 examined whether home-based strength training during adjuvant chemotherapy improves relative dose intensity and reported toxicities. One hundred eighty-one patients were randomised (mean age 55.2 ± 12.8 years; 95 men, 52.5%), 90 to the training group and 91 to usual care; training took place twice weekly at home. Mean relative dose intensity did not differ ($79\% \pm 19\%$ under training versus $82\% \pm 19\%$ under usual care; mean difference -0.04; 95% CI -0.09 to 0.02), and assignment to training did not significantly reduce the number of moderate or severe symptoms²⁵. Whether a relevant difference in dose intensity exists remains open. Whether other training forms or more intensive supervision can change this is an open question.

In type 2 diabetes, a post-hoc analysis of the Italian Diabetes and Exercise Study from 2026 examined mortality after a one-year supervised exercise programme. Six hundred six physically inactive participants were randomised 1:1: one group received twice-weekly progressive supervised endurance and strength training plus exercise counselling, the control group received counselling only. Mortality was not a primary endpoint of the original study. Whether longer or differently dosed programmes influence mortality remains to be examined.

It showed positive effects on cognition (SMD 0.34; 95% CI 0.13 to 0.55), on the HbA1c value (SMD -0.35; 95% CI -0.48 to -0.22) and on the lipid profile (total cholesterol SMD -0.20; 95% CI -0.34 to -0.07; LDL ...) ⁴. Heterogeneity was handled via a fixed or random model according to I^2 . Which share of the effect is attributable to the combination versus the single modalities is not finally clarified.

Combined training increased body weight and fat-free mass more than endurance training alone, with a trend toward greater gains in muscle mass and cross-sectional area; versus strength training alone, no significant differences were observed ³⁴. The findings concern body composition, not function. Whether the combination is superior long-term remains open.

Exercise improved flow-mediated dilatation (SMD 0.99; 95% CI 0.69 to 1.29), lowered pulse-wave velocity (SMD -0.31; 95% CI -0.44 to -0.18) and reduced carotid intima-media thickness (SMD -0.20; 95% CI -0.36 to -0.05). In the descriptive rankings, a hybrid or mixed programme achieved the greatest improvement in flow-mediated dilatation ³⁵. The ranks rest on indirect comparisons; what share strength training contributes is not reported separately.

Endurance training, combined endurance and strength training, mind-body modalities and high-intensity interval training were significantly associated with lower systolic blood pressure; high-intensity interval training at 690 metabolic equivalent minutes per week was most effective (-5.07 mmHg; 95% CrI -9.20 to -0.92). For diastolic blood pressure, endurance training and high-intensity interval training were significantly associated with reductions, strongest at 830 metabolic equivalent minutes per week (-4 ...) ³⁹. Strength training alone does not appear among the strongest modalities here; its contribution within the combination is not isolated.

The authors compared modalities and quantified dose thresholds. What role strength training alone plays for kidney function cannot be read separately from this analysis.

Under combined endurance and strength training, depressive symptoms improved markedly (SMD -1.39; 95% CI -1.80 to -0.96; $p = 0.000$). In subgroups the effect was particularly pronounced in middle-aged and older patients as well as in moderate depression; a mean duration of 9 to 24 weeks, a frequency of 3 to 4 sessions per week and a weekly total volume of more than 180 minutes appeared favourable ³⁸. The subgroups are exploratory; whether the combination is superior to the single modality was not examined.

Strength training (SMD -0.68; 95% CI -0.90 to -0.46) and mind-body modalities (SMD -0.54; 95% CI -0.72 to -0.37) were the most effective forms against depressive symptoms, followed by endurance training (SMD -0.31; 95% CI -0.50 to -0.13) and mixed training (SMD -0.23; 95% CI -0.44 to -0.01). In addition, a U-shaped dose-response relationship was found between total training dose and depressivity ²². The ranking rests on indirect comparisons; the optimal dose for different baseline conditions remains to be determined.

Mind-body modalities, combined endurance and strength training as well as endurance training improved depressive symptoms significantly; strength training alone did not. For anxiety, mind-body modalities and endurance training showed significant improvements, with mind-body modalities strongest for both endpoints. The dose-response analysis yielded a non-linear U-shaped relationship with optimal doses of 770 and 700 metabolic equivalent minutes per week respectively ³¹. For strength training alone the result here is neutral; whether certain subgroups nevertheless benefit remains open.

The nodes included endurance, strength, mind-body and multicomponent exercise, digital or virtuality-based exercise, cognitive training and combinations ³². The work compares the modalities with one another; what independent contribution strength training makes cannot be read from the reported excerpt.

In healthy adults, a randomised study from 2026 examined the influence of strength training on biological brain ageing markers. Local analyses showed increased prefrontal functional connectivity after heavy training, while moderate and heavy strength training significantly lowered the modelled brain-age value by 1.4 to 2.3 years ($p_{FDR} < 0.05$) ³⁷. The brain-age models derive from an independent dataset; whether the reduction is accompanied by clinical endpoints has not yet been examined.

For bone density at the lumbar spine, femoral neck, total hip, trochanter and Ward's triangle, moderate intensity three times per week achieved the highest rank probabilities (SUCRA 80.3%, 75.2%, 68.2%, 86.0% and 80.5%). For whole-body bone density, high intensity twice per week achieved the highest rank (SUCRA 88.9%). Versus control, moderate intensity three times per week significantly increased bone density at the femoral neck ⁴⁷. The ranks are probabilities, not confirmed superiorities; direct comparisons of the intensities are lacking.

The higher training-volume group showed a stronger pain reduction immediately after the intervention (SMD -0.88; 95% CI -1.39 to -0.36) and also beyond the intervention period (MD -1.66; 95% CI -3. ...) ⁴⁵. The authors rated the certainty of evidence according to GRADE. Whether higher volume also improves function long-term is not finally clarified.

Strength training plus electrical stimulation achieved the greatest improvements in balance and lower-limb motor function; strength training plus stretching achieved the best improvement in walking ability. The rank probabilities (SUCRA) identified strength training plus electrical stimulation as the most effective option for balance (91.13%) and motor function (79.70%), and strength training plus stretching for walking ability (96.34%) ³⁶. The ranks rest on indirect comparisons; which combination applies to which phase after stroke remains open.

Strength training lowered the incidence of lymphoedema (odds ratio 0.25; 95% CI 0.19 to 0.32) and the incidence of moderate to severe lymphoedema (odds ratio 0.21; 95% CI 0.16 to 0.29) and reduced upper-limb volume (MD ...) ³³. The work compared strength training with non-strength-focused exercise, usual care or alternative approaches. Whether the effects persist beyond the intervention duration has not yet been clarified.

In adults under 50 years, a meta-analysis from 2023 examined twelve studies with 266 participants for the combination of strength training and creatine supplementation versus strength training and placebo regarding fat mass. The combination led to a very small but significant reduction in body-fat percentage (-1.19%; $p = 0.006$), while absolute fat mass did not differ (-0.18 kg; $p = 0.76$) ⁴⁸. A second evaluation of the same evidence reports a non-significant reduction of -0.09 kg ($p = 0.88$) for absolute fat mass ⁴⁹. The participant number is small; the effects on body-fat percentage are to be classified as very small. Whether the change is clinically relevant remains to be examined.

In older adults, an observational study from 2021 examined 46 participants with placebo and 48 with metformin to determine whether muscle lipid content, assessed by computed tomography, is associated with self-reported physical function, laboratory-measured performance and the response to progressive strength training, and how metformin alters these responses. Intermuscular adipose tissue was, contrary to earlier reports, associated neither with baseline function nor with the training response. Thigh muscle density remained strongly and independently positively associated with function and performance after adjustment. Baseline density was inversely associated with strength gains, independent of muscle mass; the percentage change in density was positively associated with improved chair-rise performance and increased type-II fibre frequency, but not with muscle hypertrophy or strength gain ⁵⁰. The study is observational; whether metformin alters the training response is an open question.

In untrained young men, a randomised study from 2021 with 28 participants (14 with saffron, 14 with placebo) examined six weeks of full-body strength training (four times weekly, three sets at 60 to 70 % of the one-repetition maximum), combined with 150 mg pure saffron immediately after each session and at the same time on non-training days. In the saffron group, anandamide (0.5 ng/ml), 2-arachidonoylglycerol (0.04 ng/ml), dopamine (0.7 ng/ml) and β -endorphin (9.4 pg/ml) rose significantly ($p < 0.05$), while no changes occurred in the placebo group. Serotonin (saffron 1.7 ng/ml, placebo 1 ng/ml) and the feeling of happiness rose in both groups, more strongly under saffron⁵¹. The sample size is small; the measured markers are intermediate. Whether they translate into clinical endpoints has not been examined.

In international female master hockey players, a triple-blind randomised study from 2025 with 22 premenopausal women (37 ± 2 years) examined eight weeks of eccentric strength training (three sessions per week in addition to regular training) with 30 g hydrolysed collagen or 32.9 g maltodextrin as placebo, each together with 500 mg vitamin C before each session. The study is small; the benefit for the tendon is an indication, not proof.

In kidney transplant recipients, a study protocol from 2026 describes a pilot study on velocity-based strength training over 12 weeks. Adults with a stable graft are randomised 1:1: one group terminates sets at 20 % velocity loss, the other performs repetitions at 50 % of individual maximum velocity⁴⁰. As this is a protocol, no results are available yet. Whether velocity-based training favourably influences kidney function and metabolism is therefore a question that remains to be answered.

In older patients with sarcopenia, a randomised study from 2025 with 140 patients examined the combination of vitamin D, heat therapy and strength training versus heat therapy and strength training alone. Both groups improved skeletal muscle mass, handgrip strength and glucose and lipid metabolism, with the combination group showing stronger improvements ($p < 0.05$). After treatment, inflammatory factors were lower and thyroid hormones higher in the combination group ($p < 0.05$). A significant negative correlation was found between 25-hydroxyvitamin D3 and myostatin in both groups ($p < 0.05$)⁴¹. The study is limited to a single site; whether the additional benefit of vitamin D persists beyond the training effect remains open.

Systematic Reviews and Mechanisms of Action

The picture is less uniform for psychological and cardiometabolic endpoints. In type 2 diabetes, a one-year supervised programme did not improve mortality over 16.2 years⁴³, whereas combined programmes favourably influenced HbA1c and lipids^{4,44}. In colon cancer, home-based training did not change the relative dose intensity of chemotherapy²⁵. For kidney disease, stroke and kidney transplantation, comparisons of combinations or protocols predominate^{36,40,46}. What is lacking are large studies that directly test strength training alone against combinations and against other modalities and capture clinical endpoints such as falls, hospital admissions or mortality.

Overall Picture

3. How Robust the Research Is

The controlled human studies are distributed across many areas, most densely in the musculoskeletal system, followed by safety questions, cognition, fatigue and metabolism. These are followed by oncology, bone, cardiovascular, inflammation and gut. At the top of the cited controlled studies are works on knee osteoarthritis, coronary heart disease, breast cancer, liver cirrhosis, sarcopenia in kidney disease and preoperative training before knee replacement. The field is therefore not limited to one area of application but is spread across many clinical situations.

Methodologically, the field rests on a broad base of randomised controlled trials and several meta-analyses, for example on the simultaneous increase in muscle strength and bone density in older adults, on protein interventions as an enhancement of the training effect, or on safety and efficacy in breast cancer. **Established:** Such reviews support statements on direction and magnitude. The weakness lies not in the number of studies but in their comparability: different training protocols, different comparison groups and frequently small, clinically preselected samples. Several of the cited works are explicitly designed as pilot or feasibility studies. Where concomitant medication was examined, the result applies to the drug, not to the training.

Strength Training Is Not a Uniform Stimulus in Studies

When studies on strength training are placed side by side, one is often comparing protocols that share only the name. High-intensity training, training with restricted blood flow and progressive training with balance components are different procedures with different target variables. A systematic review makes dosage itself the subject and asks how training dose affects pain and physical function in knee osteoarthritis.

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A statement about "strength training" can therefore be derived only to a limited extent; statements about a specific protocol in a specific group are robust.

A second point concerns the accompanying circumstances. In a randomised, double-blind, placebo-controlled multicentre study, metformin attenuated muscle gain under progressive strength training in older adults. This is a finding about a drug interaction, not about the training — and it shows that training results depend on factors outside the protocol. Likewise, a protein-rich diet alters the effect on fat-free mass and hand strength. Anyone reading training studies must therefore ask what was given, measured and omitted alongside.

4. What Is Often Claimed — and What the Data Provide

STATEMENT	STUDY SITUATION
Strength training builds muscle mass equally reliably in everyone	In a randomised, double-blind multicentre study, metformin attenuated muscle gains during progressive resistance training in older adults. Concomitant medicati
Strength training acts equally on muscle and bone	A meta-analysis examines concurrent increases in muscle strength and bone density in older adults. Bone is a distinct field with markedly fewer studies than the
The results apply to trainees of all ages	The studies focus on older and clinically pre-selected groups; some works involve young people with cerebral palsy. It remains open whether the findings can be
More load brings more	A systematic review is dedicated to the training dosage and its consequences for pain and function in knee osteoarthritis. Die Dosis ist eine eigene Forschungsfr

5. The Most Robust Studies

Ordered by strength of evidence, not by familiarity: systematic reviews and studies with many participants first. The complete evaluation comprises considerably more studies; the most robust are listed here.

Controlled Human Studies

- ¹ The effect of progressive resistance training on aerobic fitness and strength in adults with coronary heart disease: A systematic review and ... (2017) — Systematic review, 1,940 participants
- ² Safety and efficacy of progressive resistance training in breast cancer: a systematic review and meta-analysis (2014) — Systematic review, 1,652 participants
- ³ Progressive Resistance Training for Improving Health-Related Outcomes in People at Risk of Fracture: A Systematic Review and Meta-Analysis of ... (2021) — Systematic review, 521 participants
- ⁴ Effectiveness of Combined Aerobic and Resistance Exercise on Cognition, Metabolic Health, Physical Function, and Health-related Quality of Life in ... (2024) — Review, 2,426 participants
- ⁵ Comparative Efficacy of Different Protein Supplements on Muscle Mass, Strength, and Physical Indices of Sarcopenia among Community-Dwelling ... (2024) — Review, 5,272 participants
- ⁶ The effectiveness of protein supplementation combined with resistance exercise programs among community-dwelling older adults with sarcopenia: a ... (2024) — Review, 854 participants
- ⁷ The influence of resistance training on inflammatory markers, body composition and functional capacity in healthy older adults: A systematic review ... (2025) — Review, 728 participants
- ⁸ Resistance exercise intervention on muscular strength and power, and functional capacity in acute hospitalized older adults: a systematic review and ... (2021) — Review, 2,498 participants
- ⁹ Effects of resistance exercise training on redox homeostasis in older adults. A systematic review and meta-analysis (2020) — Review, 614 participants
- ¹⁰ The effect of resistance training on patients with secondary sarcopenia: a systematic review and meta-analysis (2024) — Review, 639 participants
- ¹¹ Training modalities for elder sarcopenic obesity: a systematic review and network meta-analysis (2025) — Review, 955 participants
- ¹² Resistance exercise interventions for sarcopenia and nutritional status of maintenance hemodialysis patients: a meta-analysis (2024) — Review, 541 participants
- ¹³ Effect of resistance exercise on physical fitness, quality of life, and fatigue in patients with cancer: a systematic review (2024) — Review, 3,843 participants
- ¹⁴ Progressive Resistance Training Program Characteristics in Rehabilitation Programs Following Hip Fracture: A Meta-Analysis and Meta-Regression (2022) — Review, 728 participants
- ¹⁵ Effects of lower-limb active resistance exercise on mobility, physical function, knee strength and pain intensity in patients with total knee ... (2024) — Review, 880 participants
- ¹⁶ Intensity Differences of Resistance Training for Type 2 Diabetic Patients: A Systematic Review and Meta-Analysis (2023) — Review, 1,491 participants

- ¹⁷ Comparative Effectiveness of Exercise and Protein-Based Interventions on Muscle Strength, Mass, and Function in Sarcopenia: A Systematic Review and ... (2025) — Review, 7,596 participants
- ¹⁸ Dose-response effects of resistance training in sarcopenic older adults: systematic review and meta-analysis (2025) — Review, 538 participants
- ¹⁹ Optimal dose of resistance training to improve handgrip strength in older adults with sarcopenia: a systematic review and Bayesian model-based ... (2025) — Review, 711 participants
- ²⁰ Optimal resistance training prescriptions to improve muscle strength, physical function, and muscle mass in older adults diagnosed with sarcopenia: a ... (2025) — Review, 951 participants
- ²¹ Influence of different exercise types on vascular endothelial function in middle-aged and older adults - A systematic review and network meta-analysis (2025) — Review, 1,123 participants
- ²² Comparative efficacy of various exercise types and doses for depression in older adults: a systematic review of paired, network and dose-response ... (2024) — Review, 5,536 participants
- ²³ Impact of exercise type, duration, and intensity on depressive symptoms in older adults: a systematic review and meta-analysis (2024) — Review, 1,346 participants
- ²⁴ Optimizing prescription of resistance training for body composition, muscle strength, and physical performance in older adults with sarcopenia: a ... (2026) — Review, 1,302 participants

6. Summary

PROVEN For healthy adults, the ACSM Position Stand from 2026 carries the central statement: Compared with no exercise, resistance training improves muscle strength, muscle size, performance, endurance, contraction speed, gait speed, balance and several measures of physical function; heavier loads ($\geq 80\%$ of the one-repetition maximum) increase voluntary strength more. For early knee osteoarthritis, there is a data base stratified by disease stage (mobility, walking distance, knee extension strength; SMD 0.46 to 0.81). In sarcopenia, moderate intensity was sufficient for many older adults. In cancer, resistance training reduced the incidence of lymphoedema; in depression, it was the most effective form tested.

PLAUSIBLE Part of the variation follows from the prescription. In the ACSM review, only a few prescription variables influenced the primary adaptations, while dose, intensity and supervision varied widely between the studies. **Hypothesis:** When two studies with the same label set different stimuli, the reported effects are likely to be explained more by the protocol than by the training. It could follow from this that future analyses do not bundle "resistance training" but report intensity, frequency and number of sets separately — and include accompanying circumstances such as metformin, protein-rich diet or vitamin D because they co-determine muscle gain and training response.

What would need to be clarified is a large study that directly compares resistance training alone against combinations and against other modalities and records clinical endpoints such as falls, hospital admission or mortality. Also open is whether higher intensities are safe and superior in frailty, which combination of load, number of sets and frequency brings the greatest additional benefit and whether strength gains translate into everyday function and prognosis — in liver cirrhosis as well as after spinal cord injury. Also the question whether velocity-based training favourably influences kidney function and metabolism awaits results; the optimal dose for different baseline conditions remains to be determined.

7. What Remains Open

- **Dosage:** Which training dose at which baseline situation brings the greatest benefit is not clarified for most areas of application.
- **Interactions:** How concomitant medication and nutrition change the training success has so far only been tested for individual active substances and nutrients.
- **Transferability:** Whether results from very elderly or clinically preselected groups are transferable to younger and healthy people remains open.

Frequently Asked Questions

How does progressive strength training differ from other training forms in the studies?

Progressive strength training is defined by the increase in load, not by a specific device. The studies include high-intensity protocols, training with restricted blood flow and combinations with balance or endurance components. One randomised study compares different training modalities in people with elevated blood pressure and reports similar improvements in endothelial function. **Established:** For other endpoints the comparability of the modalities remains open.

How should the study situation in cancer patients be classified?

Oncological studies examine strength training in breast cancer, head and neck tumours and pancreatic carcinoma, partly before or during radiotherapy. One review on breast cancer examines safety and efficacy together; other studies report body composition, nutritional status and patient-reported outcomes. **Established:** A systematic review exists for safety and feasibility. Whether course parameters such as complications change is an open question.

Which endpoints are measured, and what do they indicate?

The studies measure muscle strength, muscle size, walking ability and balance, but also pain, quality of life, body composition and laboratory values such as interleukin-6. A measured value is not the same as disease progression. **Established:** Meta-analyses support statements on strength and fat-free mass. Whether these translate into changes in disease progression is examined in separate studies, for example on fall risk in care facilities.

Sources

- 1 The effect of progressive resistance training on aerobic fitness and strength in adults with coronary heart disease: A systematic review and meta-analysis of randomised controlled trials
Hollings M, Mavros Y, Freeston J, Fiatarone Singh M · 2017
- 2 Safety and efficacy of progressive resistance training in breast cancer: a systematic review and meta-analysis
Cheema BS, Kilbreath SL, Fahey PP, Delaney GP, Atlantis E · 2014
- 3 Progressive Resistance Training for Improving Health-Related Outcomes in People at Risk of Fracture: A Systematic Review and Meta-Analysis of Randomized Controlled Trials
Ponzano M, Rodrigues IB, Hosseini Z, Ashe MC, Butt DA, Chilibeck PD et al. · 2021
- 4 Effectiveness of Combined Aerobic and Resistance Exercise on Cognition, Metabolic Health, Physical Function, and Health-related Quality of Life in Middle-aged and Older Adults With Type 2 Diabetes Mellitus: A Systematic Review and Meta-analysis
Zhang J, Tam WWS, Hounsri K, Kusuyama J, Wu VX · 2024
- 5 Comparative Efficacy of Different Protein Supplements on Muscle Mass, Strength, and Physical Indices of Sarcopenia among Community-Dwelling, Hospitalized or Institutionalized Older Adults Undergoing Resistance Training: A Network Meta-Analysis of Randomized Controlled Trials
Liao CD, Huang SW, Chen HC, Huang MH, Liu TH, Lin CL · 2024
- 6 The effectiveness of protein supplementation combined with resistance exercise programs among community-dwelling older adults with sarcopenia: a systematic review and meta-analysis
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